Impact of Thin Film Thermophysical Properties on Thermal Management of Wide Bandgap Solid-State Transistors

A.N. Smith C, S
U.S. Naval Academy, Annapolis, MD, U.S.A.

Wide bandgap semiconductor solid-state transistors continue to have a wide array of applications that include power supplies, communications, electronic warfare, and multifunctional RF systems. Two viable wide bandgap semiconductor materials currently under investigation are Silicon Carbide (SiC) and Gallium Nitride (GaN). One interesting aspect of these devices is their ability to operate at elevated temperatures on the order of 150 ºC. At higher temperatures the heat capacity of semiconductors becomes constant, while the phonon mean free path is inversely proportional to the lattice temperature. This causes a significant reduction in the thermal conductivity over this temperature range. The active region of these devices can create heat fluxes in excess of 1 kW/cm2. Since these heat fluxes occur near the active region, quantifying the thermophysical properties of the underlying thin film materials is of critical importance. Several techniques that have been used to study the thermophysical properties of wide bandgap semiconductor thin films will be reviewed. Experimental results will be presented for the thermal conductivity of the GaN samples measured using the 3w technique. The GaN samples used in the study were several micron thick films deposited using metal-organic vapor phase epitaxy MOVPE on 4H SiC, 6H SiC, and sapphire substrates. The thermal conductivity of GaN will be presented as a function of temperature from 300 K to 500 K. The influence of the temperature dependent thermal conductivity on the thermal performance of these devices will be demonstrated.